Available online at www.sciencedirect.com
ScienceDirect
Journal of Forensic and Legal Medicine 15 (2008) 462–466
JOURNAL OF FORENSIC AND LEGAL MEDICINE
www.elsevier.com/jflm

Case Report

Unusually extensive head trauma in a hydraulic elevator accident: Post-mortem MSCT findings, autopsy results and scene reconstruction

Christina Jacobsen MD PhD (Medical Doctor) [a,b], Corinna A. Schön Dr Med (Medical Doctor) [a,*], Beat Kneubuehl Dipl Math Dr Sc Forens (Mathematician and Physicist) [c], Michael J. Thali Dr Med (Medical Doctor) [a], Emin Aghayev Dr Med (Medical Doctor) [a]

[a] *Centre for Forensic Medicine and Virtopsy, University of Bern, Buehlstrasse 20, CH-3012 Bern, Switzerland*
[b] *University of Copenhagen, Department of Forensic Medicine, Frederik d V's Vej 11, 2100 Copenhagen Ø, Denmark*
[c] *Centre for Forensic Physics and Ballistics, University of Bern, Buehlstrasse 20, 3012 Bern, Switzerland*

Received 5 December 2007; accepted 6 March 2008
Available online 11 July 2008

Abstract

Accidental or intentional falls from a height are a form of blunt trauma and occur frequently in forensic medicine. Reports describing elevator accidents as a small subcategory of falls from heights are rare in the medical literature and no report on injury patterns or scene reconstruction of such an accident was found. A case of an accident in a hydraulic elevator with a man falling 3 m was examined using post-mortem multi-slice computed tomography (MSCT) and autopsy. The man suffered an unusually extensive trauma and died at the scene. Post-mortem MSCT examination showed a comminute fracture of the skull, the right femur and the first lumbar vertebra. Severe lacerations of the brain with epidural, subdural and subarachnoidal haemorrhages over both hemispheres were diagnosed. Autopsy confirmed these findings. To reconstruct the accident we used radiological and autopsy results as well as findings at the scene.

Keywords: Virtopsy; Forensic radiology; Elevator accident; Computed tomography; Skull fracture

1. Introduction

Accidental or intentional falls from a height representing a form of blunt trauma occur frequently in forensic medicine, but elevator accidents form a small subcategory within the falls from heights.[1] The reports describing elevator accidents are rare in the medical literature and no report on injury patterns or scene reconstruction of such an accident was found.

According to Gupta et al.[2] injury patterns of persons who die after a fall from a height can be variable. The fall related injuries can be caused by direct impact resulting in severe injuries of the impacted body region or by indirect force leading to injuries in a body region distant from the impact. Severity of the injuries can be influenced by a number of factors such as the distance of the fall, the body orientation and the material of the impact surface.[3–5]

A fatal occupational accident in an elevator with the victim falling 3 m was examined using post-mortem multi-slice computed tomography (MSCT), which is currently performed in selected cases at our institute. The documented skull fracture far exceeded the expected injury after a low fall. The aim was to reconstruct the accident using the radiological and autopsy results as well as findings at the scene.

2. Materials and methods

2.1. Case

A 48-year old elevator maintenance worker was working on the platform of an elevator still under construction

* Corresponding author. Tel.: +41 31 631 84 11; fax: +41 31 631 38 33.
E-mail address: corinna.schoen@irm.unibe.ch (C.A. Schön).

1752-928X/$ - see front matter © 2008 Elsevier Ltd and FFLM. All rights reserved.
doi:10.1016/j.jflm.2008.03.006

when suddenly the platform dropped from the ground level 3 m downwards to the basement level. The man died at the scene (Fig. 1). The only witness saw him standing upright with both feet on the platform during the fall.

2.2. Data of the elevator

The elevator was used for transporting goods from the ground to the basement. The platform measured 4 × 2 m and weighed around 1500 kg. It was moved by electric hydraulics, using the so-called piggyback system (Fig. 2). The middle hydraulic pillar was responsible for transporting the platform to an intermediate stop, which was located 3 m below the ground floor. At this stop the platform became connected with two external hydraulic pillars by bolts and subsequently was transported by the pillars to the ground floor. During construction of the elevator the maintenance worker had to check audibly whether the bolts locked in at the intermediate stop.

Fig. 1. The scene with the victim lying on the elevator platform in a pool of blood. The arrow indicates the smeared blood including downward oriented blood spatters and traces of brain tissue at the back wall of the elevator shaft.

Fig. 2. Photograph demonstrating the electric hydraulics, so called piggyback-system. The middle hydraulic pillar was responsible for transporting the platform to an intermediate stop, where the platform is connected with the two other outside hydraulic pillars by bolts. Subsequently, the outside pillars transported the platform from the intermediate stop to the ground floor.

2.3. Post-mortem MSCT

A post-mortem MSCT of the body was performed using a 6-row scanner (Emotion 6, Siemens, Germany) prior to autopsy. A collimation of 6 × 1.25 mm, a slice thickness of 1.0 mm and reconstruction kernels B30's and B80's were used. A three-dimensional volume rendering reconstruction was performed using a musculoskeletal protocol.

For further data segmentation MIMCS software (Materialise, Leuven, Belgium) was used.

3. Results

3.1. External inspection

At the scene the victim was lying in a right lateral position across the platform (Fig. 1). There were extensive blood spatters on the platform and the shaft. At the back wall of the shaft, around 1.5 m above the platform level smeared blood with downward oriented blood spatters and traces of brain tissue were observed.

Fig. 3. External inspection of the body shows an open head injury with an extensive galea laceration, skull fracture and severe brain laceration.

Fig. 4. The 3D reconstruction of the MSCT data of the skull presents an extensive spider web fracture system: (a) frontal view; (b) left lateral view and (c) posterior view.

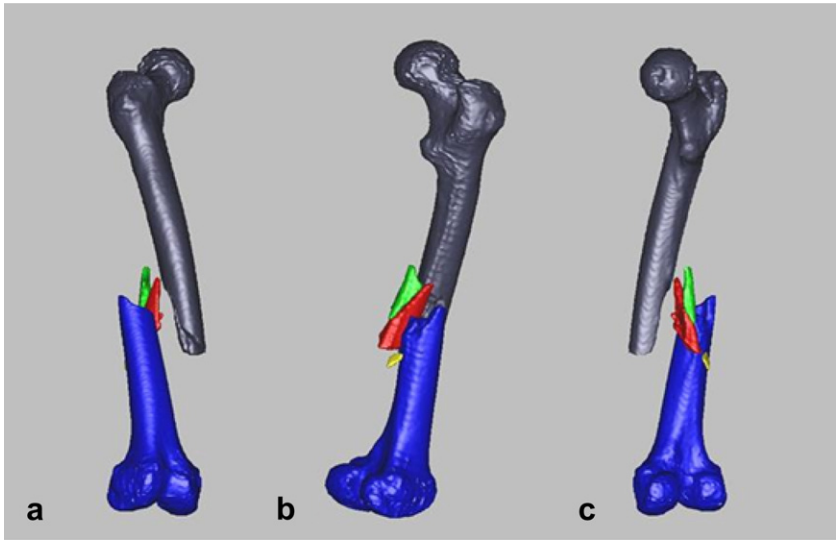

Fig. 5. The 3D reconstruction and segmentation of the right femur demonstrate the compression-angulation fracture with three differently coloured fragments: (a) angled frontal view; (b) angled lateral view and (c) angled posterior view.

An open head injury with a contusion wound at the occiput was detected (Fig. 3). The right femur showed a malposition as a sign of a fracture.

3.2. Imaging

The MSCT demonstrated an extensive spider web skull fracture with impact point at the occiput (Fig. 4). Here the skull was flattened with circumferential fractures and fractures radiating into the skull base (Fig. 4). The comminuted skull fracture involved the entire vault and all three cranial fossae bilaterally. Severe laceration of the brain with pneumocephalus, an extensive frontal epidural haemorrhage with bilateral loosening of the dura from the bone and subdural and subarachnoidal haemorrhages over both hemispheres were diagnosed.

Furthermore, a compound compression-angulation fracture of the right femur (Fig. 5) and an anterior compression fracture of the first lumbar vertebra were detected.

3.3. Autopsy

The autopsy of the 110 kg heavy man confirmed all radiological findings. Additionally to the imaging, symmetrically located bleeding in both nuclei dentati, in the cerebellum and brainstem haemorrhages were seen. Distinct paleness of the internal organs was observed. No further relevant findings were diagnosed.

4. Discussion

In low falls from up to 9 m head injuries are common and mostly lethal.[2,5–10] It is suggested that the high incidence of head injuries in free low falls is due to the body orientation along its centre of gravity.[2,9] With increasing height the head injuries are associated with other lethal injuries.[2]

In the presented case, the head sustained a major impact. MSCT scan findings of the skull showed an unusually extensive spider web fracture with a large impressed area of the

back of the skull, suggesting that the injury was caused by an impact on a broad flat surface (Fig. 4). It has previously been reported that a fall onto a broad flat surface can result in a comminuted fracture with flattening of the skull at the impact point.[2] Corresponding circular fractures often represent the degree of inbending of the skull.[11]

The fracture of the right femur was diagnosed in MSCT as a compression-angulation fracture.[12] The lumbar vertebral fracture was diagnosed as an anterior compression fracture. Both are fractures typical for feet-first injuries through axial loading.[2,10,13–15]

Attempting a reconstruction of the accident we assumed that initially both, the platform and the deceased, fell simultaneously with the gravitational force. As the deceased was observed standing on the platform before the fall and as the fall depth was only 3 m, the various possibilities for body orientation as described and analysed in the literature in typical free-falls[2,4] were not given in this case. This supports the witness description of a "feet-first" fall. It is exemplified by the fact that the diagnosed characteristic femur and vertebral fractures are typically caused by an axial load.[13,14]

The impact of the elevator at the base was a typical inelastic collision with a small recovery of kinetic energy (ke). Therefore, the platform accelerated upwards, gave an additional force to the deceased and accelerated him upwards. Assuming a realistic ke recovery factor of 5%, the force acting on the body was about 1 ton and he was catapulted back with an initial velocity that should result in a height of about 6.5 m. The findings at the scene with smeared blood with downward oriented blood spatters and traces of brain tissue at the back wall of the elevator shaft (Fig. 1) suggest that the upward acceleration was stopped by a head-impact of the deceased on the back wall of the elevator shaft. This impact and possibly the following fall onto the platform must have resulted in the presented massive deformation of the skull.

Because of the transformation of the falling platforms kinetic energy into a subsequent axial force affecting the deceased man the overall kinetic energy was greater in this case compared to the kinetic energy acting on a body by a simple 3 m fall onto the ground. This caused the distinct fractures of the axial skeleton and the comparatively massive deformation of the skull.

In the presented case post-mortem MSCT correctly diagnosed the skeletal injuries. The fact that the body was scanned prior to autopsy allowed for demonstration of the skull fracture pattern in situ (Fig. 4), which was important for the case assessment. The reconstruction of the radiological data using volume rendering reconstruction excelled by its three-dimensional visualisation of the extensive skull fracture.

In addition to the imaging, the autopsy showed cerebellum and brainstem haemorrhages. The latter being considered the cause of death. Post-mortem magnetic resonance imaging examination, providing better soft tissue contrast compared to MSCT would be the method of choice for radiological presentation of the cerebellum and brainstem haemorrhages as previously reported.[16–18]

In conclusion, in an elevator accident in addition to the height of a fall, the circumstances of an accident contribute to the severity of the injuries and therewith to a fatal outcome. Exact reconstruction of elevator accidents is essential for assessment of forensic cases as well as for the elevator construction industry.

Post-mortem MSCT proved to be a useful rapid and non-invasive documentation and reconstruction tool for examination of forensic cases with traumatic injuries.

Conflict of interest statement

None.

Acknowledgements

We are grateful to Urs Koenigsdorfer (Institute of Forensic Medicine, University of Bern) for the excellent help at the forensic autopsy, M.D. Andreas Christe (Institute of Diagnostic Radiology, University Hospital of Bern) for the radiological diagnoses and M.D. Stephan Bolliger (Institute of Forensic Medicine, University of Bern) for support editing the paper.

References

1. McCann M. Deaths in construction related to personnel lifts, 1992–1999. *J Safety Res* 2003;**34**:507–14.
2. Gupta SM, Chandra J, Dogra TD. Blunt force lesions related to the heights of a fall. *Am J Forensic Med Pathol* 1982;**3**:35–43.
3. Aufmkolk M, Voggenreiter G, Majetschak M, et al. Injuries due to falls from a great height. A comparative analysis of injuries and their outcome following suicide-related and accidental falls. *Unfallchirurg* 1999;**102**:525–30.
4. Christensen AM. The influence of behaviour on freefall injury patterns: possible implications for forensic anthropological investigations. *J Forensic Sci* 2004;**49**:5–10.
5. Goren S, Subasi M, Tyrasci Y, et al. Fatal falls from heights in and around Diyarbakir, Turkey. *Forensic Sci Int* 2003;**137**:37–40.
6. Helling TS, Watkins M, Evans LL, et al. Low falls: an underappreciated mechanism of injury. *J Trauma* 1999;**46**:453–6.
7. Li L, Smialek JE. The investigation of fatal falls and jumps from heights in Maryland (1987–1992). *Am J Forensic Med Pathol* 1994;**15**:295–9.
8. Mathis RD, Levine SH, Phifer S. An analysis of accidental free falls from a height: the 'spring break' syndrome. *J Trauma* 1993;**34**:123–6.
9. Turk EE, Tsokos M. Pathologic features of fatal falls from height. *Am J Forensic Med Pathol* 2004;**25**:194–9.
10. Yagmur Y, Guloglu C, Aldemir M, et al. Falls from flat-roofed houses: a surgical experience of 1643 patients. *Injury* 2004;**35**:425–8.
11. Gurdjian ES, editor. Deformation studies of the skull: mechanisms of skull fracture. In: Impact head injury, Charles C. Thomas: Springfield; 1975. p. 113–25.
12. DiMaio DJ, DiMaio VJ. *Forensic pathology*. Amsterdam, New York: CRC Press; 1992.
13. Beale JP, Wyatt JP, Beard D, et al. A five year study of high falls in Edinburgh. *Injury* 2000;**31**:503–8.
14. Teh J, Firth M, Sharma A, et al. Jumpers and fallers: a comparison of the distribution of skeletal injury. *Clin Radiol* 2003;**58**:482–6.

15. Richter D, Hahn MP, Ostermann PA, et al. Vertical deceleration injuries: a comparative study of the injury patterns of 101 patients after accidental and intentional high falls. *Injury* 1996;**27**:655–9.
16. Yen K, Weis J, Kreis R, et al. Line-scan diffusion tensor imaging of the posttraumatic brain stem: changes with neuropathologic correlation. *Am J Neuroradiol* 2006;**27**:70–3.
17. Thali MJ, Yen K, Schweitzer W, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)-a feasibility study. *J Forensic Sci* 2003;**48**:386–403.
18. Thali MJ, Braun M, Buck U, et al. VIRTOPSY – scientific documentation, reconstruction and animation in forensic: individual and real 3D data based geo-metric approach including optical body/object surface and radiological CT/MRI scanning. *J Forensic Sci* 2005;**50**:428–42.